CONTROL STRATEGIES AND APPLICATIONS OF THREE-PHASE DIRECT MATRIX CONVERTERS

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CONTROL STRATEGIES AND APPLICATIONS OF THREE-PHASE DIRECT MATRIX CONVERTERS

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DECLARATION

I declare that this thesis is submitted in fulfilment of the requirements for the ward of PhD degree in the Faculty of Engineering and Information Technology at the University of Technology Sydney. I certify that the work in this thesis has not been previously submitted, in part or whole, to any organizations for a degree or other qualifications.

This dissertation is the result of my own original work and the collaboration is fully acknowledged in this thesis. The literature and information sources used in this thesis are indicated.

Jianwei Zhang

Signed:______________________________________________________________

Date:________________________________________________________________

Production Note:
Signature removed prior to publication.
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ABSTRACT

AC-to-AC converters have been widely used in various areas in the real world. In industrial applications, the AC-to-AC power conversion is usually accomplished by indirect converters. In these traditional converters, AC power is firstly converted into DC power by a rectifier, and then the DC power is converted into AC power by an inverter. The rectifier and inverter are usually connected via an intermediate bulky DC-link capacitor. The use of the DC-link capacitor in these converters makes the equipment volume bulky, reduces the lifetime, increases the design complexity and decreases the system efficiency. Therefore, it is of great benefit to remove the bulky DC-link capacitor or propose new converter topologies. A matrix converter (MC) does not require large energy storage elements and it has emerged as a potential solution to AC-to-AC conversion.

A three-phase direct MC comprises nine bidirectional semiconductor switches arranged in a 3×3 matrix form to realize the direct AC-to-AC conversion. Thanks to benefits such as bidirectional power flow, compact volume, controllable input power factor and sinusoidal waveform, MCs have attracted research interests and plenty of projects on MC have been reported. MC is also regarded as an all-silicon converter. However, there are some drawbacks associated with MCs and they have very limited industrial applications. These drawbacks include low voltage transfer ratio (VTR), sensitivity to the grid variations and complex modulation. Some MC application areas need more exploration. The work in this thesis is carried out to contribute to possible solutions to some of the above issues by investigating some control strategies and applications of MCs.

The main contributions included in this work are summarized as follows:

(1) A simple decoupling controller is designed for the MC-based unified power flow controller (UPFC) (MC-UPFC) to regulate the power flow in a transmission system. The controllable regions of the MC-UPFC are also analyzed. A design procedure for the closed-loop controller in the MC-UPFC is presented.

(2) A modified PI controller is proposed for the improvement of the steady-state performance by including a current feedforward path. More control flexibility is provided because of the feedforward controller. A PR controller is designed for the MC and this has good performance.
(3) A hysteresis current controller is proposed for the MC to drive AC motors. Both fixed-band and sinusoidal-band hysteresis controllers are investigated, and their performance is compared. The hysteresis controller is a very simple and practical controller for the MC. For the MC-based motor drive, a direct torque control (DTC) technique is also investigated.

(4) Model predictive control (MPC) is investigated to control the MC. This scheme is used in an MC-based microgrid. In the islanded mode, predictive voltage control is employed to regulate the MC output voltages to supply various loads. An improved VTR is observed. When the microgrid is connected to the utility grid, power flow is the main objective. The performance of the controller is tested under various conditions including input disturbance and different loads.

(5) An MC prototype is built to support the research. The prototype hardware includes main circuit, drives, supplies, analog to digital conversion (ADC) conditioning circuits, and sensor board. The algorithm is implemented in Matlab Simulink with C2000 hardware support packages for TI DSP processors. Various experimental tests are carried out to support the proposed strategies.
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<tbody>
<tr>
<td>AC</td>
<td>Alternating Current</td>
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<tr>
<td>ADC</td>
<td>Analog to Digital Converter</td>
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<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>DSP</td>
<td>Digital Signal Processor</td>
</tr>
<tr>
<td>DTC</td>
<td>Direct Torque Control</td>
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<tr>
<td>ePWM</td>
<td>Enhanced Pulse Width Modulator</td>
</tr>
<tr>
<td>eQEP</td>
<td>Enhanced Quadrature Encoder Pulse</td>
</tr>
<tr>
<td>FACTS</td>
<td>Flexible Alternating Current Transmission System</td>
</tr>
<tr>
<td>FFT</td>
<td>Fast Fourier Transform</td>
</tr>
<tr>
<td>F-HB</td>
<td>Sinusoidal Hysteresis Band</td>
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<td>FOC</td>
<td>Field Oriented Control</td>
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<tr>
<td>HB</td>
<td>Hysteresis Band</td>
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<td>IGBT</td>
<td>Insulated Gate Bipolar Transistor</td>
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<td>KCL</td>
<td>Kirchhoff Current Law</td>
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<tr>
<td>KCL</td>
<td>Kirchhoff Current Law</td>
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<td>MC</td>
<td>Matrix Converter</td>
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<td>MC-UPFC</td>
<td>Matrix Converter based Unified Power Flow Controller</td>
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<tr>
<td>MPC</td>
<td>Model Predictive Control</td>
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<tr>
<td>PI</td>
<td>Proportional Integral</td>
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<td>PICF</td>
<td>Proportional Integral Controller with Current Feedforward</td>
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<tr>
<td>PI-SVM</td>
<td>Proportional Integral Controller based on Space Vector Modulation</td>
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<tr>
<td>PLL</td>
<td>Phase Locked Loop</td>
</tr>
<tr>
<td>PMSM</td>
<td>Permanent Magnet Synchronous Machine</td>
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<tr>
<td>PR</td>
<td>Proportional Resonant</td>
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<td>PRHC-SVM</td>
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<td>PWM</td>
<td>Pulse Width Modulation</td>
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<td>Serial Communications Interface</td>
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<tr>
<td>S-HB</td>
<td>Fixed Hysteresis Band</td>
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<td>Sliding Mode Control</td>
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<tr>
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<td>VTR</td>
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